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Final Report
for Option 2 Contract Year

Cost and Schedule Analytical Techniques Development

Contract NAS8-40431

December 1997

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Prepared for:
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Final Report

Cost and Schedule Analytical Techniques Development
Contract NAS8-40431, Option 2 Year
December 1, 1996 Through November 30, 1997

I. INTRODUCTION

This Final Report summarizes the activities performed by Science Applications International Corporation (SAIC) under contract NAS8-40431 "Cost and Schedule Analytical Techniques Development" (CSATD) for the Option 2 Year from December 1, 1996 through November 30, 1997. The Final Report is in compliance with Paragraph 5 of Section F of the contract.

This CSATD contract provides products and deliverable in the form of models, data bases, methodologies, studies and analyses for the NASA Marshall Space Flight Center's (MSFC) Engineering Cost Office (PP03) the Program Plans and Requirements Officer (PPO2), and other user organizations. Detailed Monthly Progress reports were submitted to MSFC in accordance with the contract's Statement of Work, Section IV "Reporting and Documentation". These reports spelled out each month's specific work accomplishments, deliverables submitted, major meetings held, and other pertinent information. This Final Report will summarize these activities at higher level.

During this contract Option Year, SAIC expended 29,830 man-hours in the performance of tasks called out in the Statement of Work and reported on in this yearly Final Report. This represents approximately 16 full-time EPs. Included are the basis Huntsville-based team, plus SAIC specialists in San Diego, Ames Research Center, Chicago, and Colorado Springs performing specific tasks for which they are uniquely qualified.

II. BASIC TASKS

The basic CSATD contract calls out three major Statement of Work task areas that provide analytical technique developments for MSFC. In this report the three task areas are actually addressed as four because REDSTAR data base and data analysis are treated separately rather than as one heading.

A number of major deliverables to NASA resulted from work under the basis tasks. These include the delivery of two versions of NAFCOM96 to some 90 government users, delivery of the Unrestricted Release NAFCOM to several hundred users, a update release of Unrestricted Release NAFCOM, delivery of a four volume set of aerospace projects' schedules, and documented results of dozens of ad hoc, quick turn-around taskings. In addition, the REDSTAR library was increased by over 1,700 documents, some 10 training courses were held around the country to train NAFCOM users, major

improvements were made to the operability and flexibility of NAFCOM including adding a functional cost breakout capability, increasing the size of the data base, and inclusion of PRICE calibration factors, to mention a few. Specific accomplishments in the four areas are discussed in the following paragraphs.

II.1 REDSTAR Data Base System Maintenance & Expansion

Approximately 1,761 documents were added to REDSTAR during 1997, bringing REDSTAR's total holdings to over 19,921. REDSTAR's growth was mainly due to the receipt of three boxes of reports from NASA Headquarters, twelve boxes from Goddard Space Flight Center (containing approximately 400 Project Management Reports dated 1971-1992), twenty boxes of reports from MSFC PP03, nine boxes from PP02, ten boxes from the SAIC Schaumburg office, and four boxes of reports for REDSTAR from the MSFC Advanced Systems and Technology Office. The REDSTAR data base also saw improvement with the completion of a project to assign a major keyword to every document.

Several outside requests for REDSTAR documents were placed. With permission, requested documents were made available to Lewis Research Center, Langley Research Center, Jet Propulsion Laboratory, Air Force Cost Analysis Agency, Princeton Synergetics, Hughes Aircraft, and Aerospace Corporation.

Data collection contacts were made during the year to enhance the REDSTAR collection. Information to place in REDSTAR was requested from the following: Jeff Osmand of JPL DSN Data Services, Ken Oppenheimer of Thiokol, Carl Stechman of Kaiser Marquardt, Ken Martin of Spar Aerospace, and Deneen Silviano of the Lean Aircraft Initiative. On-line data bases such as NASA-Recon, along with other data bases available through the Internet or Redstone Scientific Information Center, were frequently queried for retrieval of pertinent information.

Research was requested by the customer to locate information on the following subjects: GaAs solar cells, liquid flyback booster, STABLE experiment, Redstone rocket, production schedules for External Tank, SRB, SSME, and IUS, NASA yearly appropriations for space transportation, Integrated Orbital Servicing Study, Space Assembly, Maintenance, and Servicing Study, LRB for STS Study, Space Station CCMS II and TCMS costs, Hubble mission operations costs and schedules, Star-24 motor costs, rocket-based combined-cycle engines, turbine-based combined-cycle engines, pulsed detonation engines, technology assessment, portfolio management, airbreathing engines, AXAF, grapple fixture costs and weight, technology investment, launch vehicle weights, Spaceborne Imaging Radar-C, SRB critical items, NEAR and Craf/Cassini instrument cost and weight, and Mightysat.

II.2 Cost Data Analysis

The NAFCOM data base for the year has undergone many changes. The Functional Cost Handbook has been created to aid the user in the use of NAFCOM's functional cost capabilities. This manual outlines the approach taken to analyze the data and identify key factors that allow the functional breakdown to be modeled. Factors such as labors rates, overhead rates, make/buy percentages, and general and administrative percentages are defined. NAFCOM data files have been converted to Access in order to provide more flexibility for there use. Access is a MS Office software that allows easier file maintainability, increased accuracy, and reduced conversion steps.

The creation of the NAFCOM Unrestricted Release has been a major but rewarding effort. The Unrestricted Release was created for circulation through the NASA and Air Force contractor world. The NAFCOM data base is the primary estimating data set but is not identified by mission or weight to the user. Data points are chosen by weight ranges and heritage is given by TRL levels in this protected release. All "As Reported" and "Modeled" cost are removed from the viewer's access. All screens and printouts are modified to reflect the changes in the data base.

Data points collected in the latter part of 1996 have been analyzed and are now included in the NAFCOM data base. They are: Toms-EP, Lewis, Mars Global Surveyor, Mars Pathfinder, Lunar Prospector, Freja, Orsted, Darpasat, and Step 0,1,2,3. Also added to the data base is Near. These data points additions continue the NAFCOM thrust toward the lower cost missions found in the late 1980's and 1990's.

Finally, we are approximately 50% finished with technical descriptions for all of the spacecraft subsystems. These descriptions are taken from actual contractor and government literature that provide in detail the technical aspects of each individual mission. These descriptive are intended to help those not as familiar with the historical data base.

II.3 Development of Cost Estimating Techniques

The most significant task completed this year in the area of cost estimating techniques was the release of the NASA/Air Force Cost Model 96 (NAFCOM 96). This parametric cost model is an update to the NASA Cost Model (NASCOM) Version 5.0 released in the fall of 1996 that incorporates Air Force specific requirements. We also developed and released an Unrestricted Release Version of NAFCOM 96 on CD-ROM, NAFCOM-UR. This version can be distributed to non-government cost estimators. The updates within these models are described in the following sections.

The work completed in several other cost estimating areas is described in sections below. This work includes: progress made on the development of an updated version of NAFCOM 96 to be entitled NAFCOM 98; an update on the NAFCOM training efforts; an improved approach to communicating the cost estimating capabilities and data bases

resident at MSFC through a newsletter and a NAFCOM web page; and a newly released CD-ROM Estimator's Toolkit.

II. 3.A NAFCOM 96 Cost Model

The NAFCOM 96 Cost Model incorporates several Air Force specific requirements into the NASCOM Version 5.0 Cost Model. The opening screen is shown below in Figure 1.

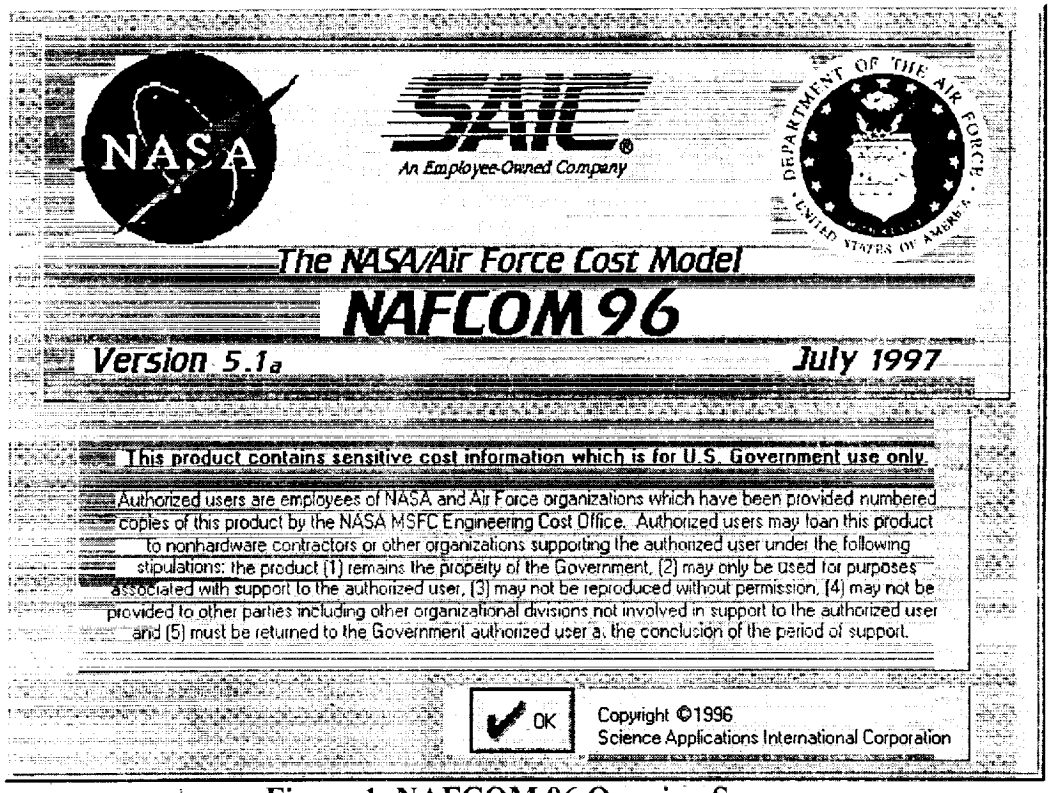


Figure 1. NAFCOM 96 Opening Screen

The Air Force requirements included additional capabilities in the application of learning curves, re-normalized data files to Air Force ground rules, and an updated version of the Functional Breakdown Structure data tables.

The Air Force required: a greater range of learning curve input percentages, the ability to estimate the continuation of a production run, and the calculation of Low Rate Initial

Production effects. Each of these new requirements were met with the input provided in the revised learning input screen shown below in Figure 2.

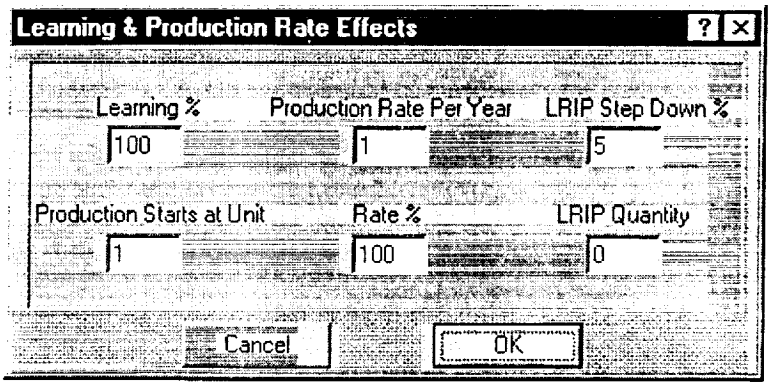


Figure 2. Revised Learning Input Screen

The largest change required by the Air Force was the re-normalization of the NAFCOM data files. This was required largely due to the differences in inflation rates between NASA and the Air Force over the past four decades. The compound effect of the difference in inflation is significant on the older programs in the NAFCOM data base as can be seen in Figure 3. Programs from the 1960's may be as much as 40% different in NASA ground rules versus Air Force ground rules.

The data normalization modification to NASCOM was accomplished by creating two sets of data files. The model calculates the cost of an estimate using the NASA data bases in NASA is selected on the Global screen for estimating methodology and Air Force data if Air Force methodology is selected. The Global input screen is shown in Figure 4.

Early in the year, in response to questions from the Air Force Cost Analysis Agency concerning the functional breakdown feature of the NAFCOM Model, we researched the data points and methods used in the functional analysis to explain large differences in some of the NASA percents-of-total and the Air Force percents-of-total that are used by the model. We looked closely at the percentages for materials cost where the major differences occurred. We began updated the NAFCOM Functional Cost Breakdown document discussing these differences in the NASA percents-of-total and the Air Force percents-of-total. The updated document was then presented to the Air Force Cost Analysis Agency. The NAFCOM Help file and the user's manual were also updated to reflect the functional cost analysis findings, as well as other suggested modifications to the model and documentation that were suggested by the AFCAA.

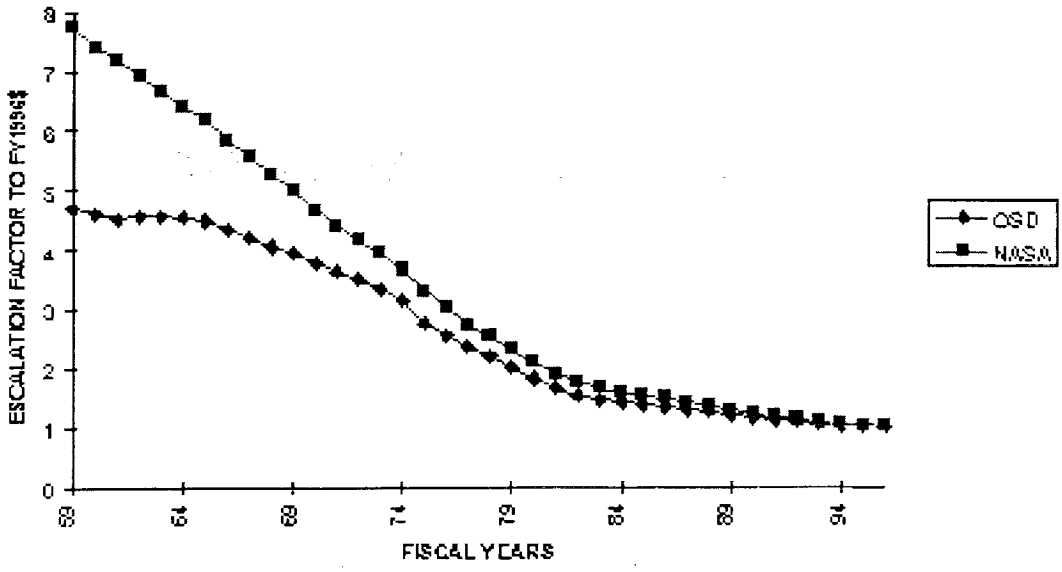


Figure 3. NASA Versus Air Force Inflation Indices

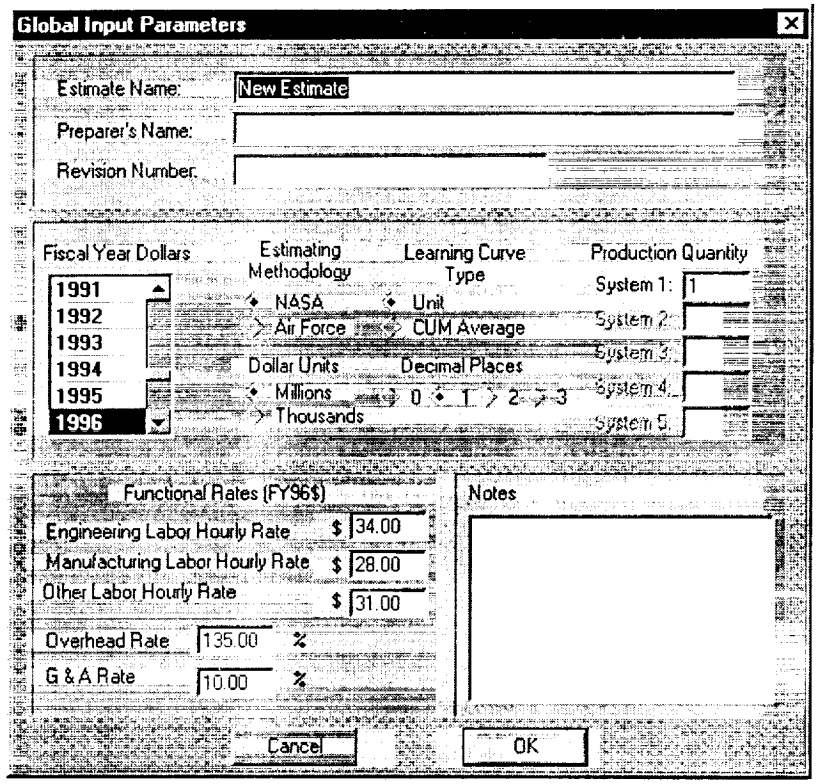


Figure 4. NAFCOM Global Input Screen

The NAFCOM Functional Breakdown Structure (FBS) capability uses default rates, average percents-of-total, and user defined functional rates to break down an estimate into its functional parts of hours, labor, material, overhead, subcontracts, other direct charges, and general and administrative expenses. The NAFCOM screen displaying the FBS cost is shown in Figure 5. below.

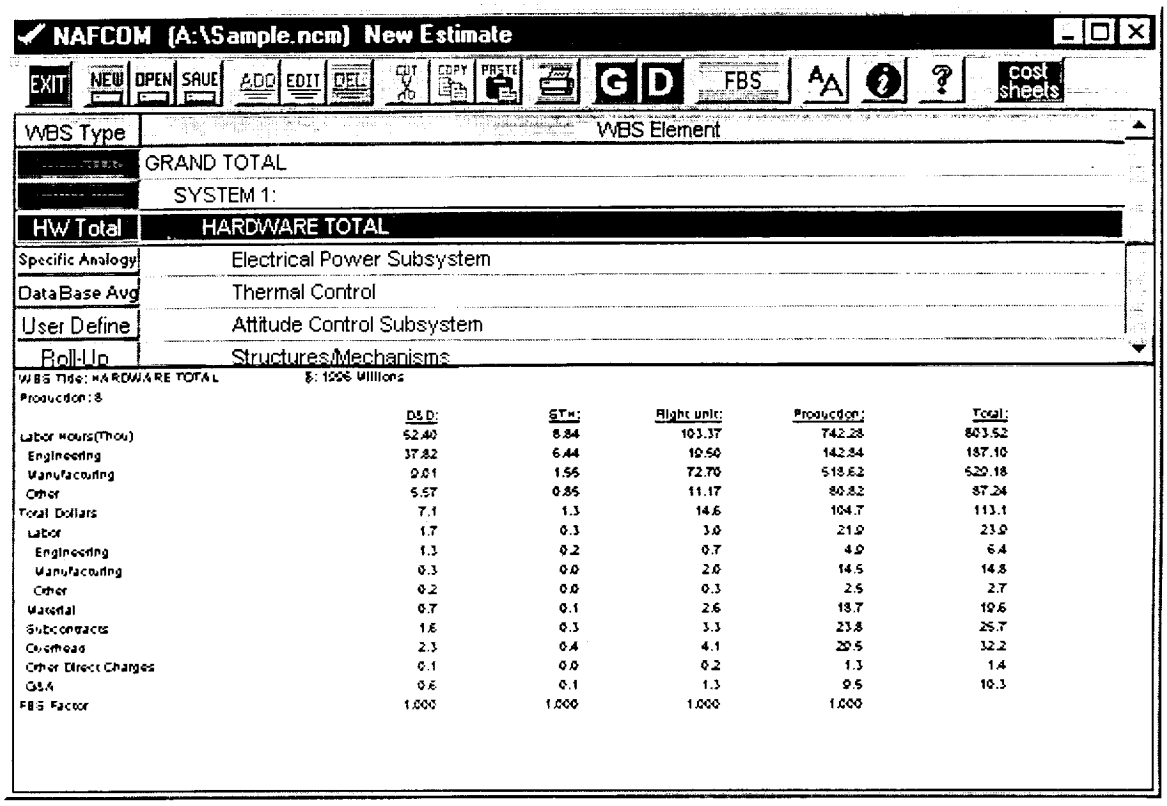


Figure 5. NAFCOM FBS Screen

NAFCOM 96 was distributed to 86 government users throughout the country. The model is being used at almost all NASA Centers and by numerous subcontractors to Government organizations.

II.3.B NAFCOM UR Cost Model

This contract year we introduced the Unrestricted Release Version of the NAFCOM Model on CD. This model is offered at no cost to interested aerospace cost analysts. It differs from the NAFCOM Government Only Version in that it will not allow access to specific project names, costs, or weights. As a result, certain filters, features, and functions are inoperable on this version to protect the sensitive data base. For the Unrestricted Release Version, data base files were modified. All "As Reported" and "Modeled" costs were removed. Weights were changed to weight ranges, and launch years were modified to launch eras. All screens and printouts were modified to reflect changes in the data base.

The NAFCOM-UR was formatted for a CD-ROM distribution. We presented the capabilities of the model at Society of Cost Estimating and Analysis (SCEA), Space Systems Cost Analysis Group (SSCAG), and International Society of Parametric Analysts (ISPA) national meetings and distributed CDs to attendees. To date we have distributed 191 copies of NAFCOM-UR.

II. 3.C NAFCOM 98 Cost Model

We began development of the NAFCOM 98 Cost Model this year after the distribution of NAFCOM-UR. This updated version of the NAFCOM Cost Model will include two new innovative features: Complexity Generators and Process Estimating.

Complexity Generators relate the cost estimate to several different cost driving variables rather than being strictly related to weight. The Air Force Cost Analysis Agency (AFCAA) has funded a portion of the development to date on the Complexity Generators and this effort is described in more detail in Section III.6, AFCAA Tasks.

The Process Estimating feature is a methodology where the cost estimating inputs and results are used by NAFCOM to estimate the processes involved in the development of space hardware and the schedule at the subsystem level. This effort to date is described in Section II.4, Scheduling since this NAFCOM work relates directly to the schedule tasks.

In addition to the two main new features of NAFCOM, we have made progress on several other improvements and enhancements to NAFCOM. The data base updates to the model are described in Sections II.1. and II.2. We have also made much progress in developing more detailed project resumes with data provided at a much lower level. We have also made several improvements to the NAFCOM software including: improved printouts, a better use of screen space, a way to increase the amount of data provided on the screen for estimating results, and a method to view project data from the data search screen.

In an effort to improve the functional breakdown structure feature of NAFCOM we have updated the labor rates used in the model and improved the way that NAFCOM handles materials and subcontracts costs. We decided that the data points that show zero dollars in all subsystems for either materials and/or subcontracts do not reflect reality and should not be included in the averages for percents-of-total. Since this cut down on the total number of analyzed data points, we decided to segregate the percents-of-total based just on responsible agency and subsystem type. Previously, we segregated the percentages based on responsible agency, subsystem type, and mission type. We have started updating the NAFCOM Functional Breakdown documentation to reflect changes in the labor rates and the average percents-of-total sets.

II. 3.D NAFCOM Training

This contract year we trained approximately 60 people to use NAFCOM Government Only Versions 5.0 and 5.1. The NAFCOM training course consists of a cost estimating overview, a NAFCOM96 background, instructions for operating the model, sample problems, and future enhancements. We conducted nine training sessions at various locations including Johnson Space Center, NASA Headquarters, Air Force Cost Analysis Agency, Ames Research Center, Langley Research Center, and SAIC. Attendees represented the centers and agencies hosting the classes, as well as, Goddard Space Flight Center, Marshall Space Flight Center, the Aerospace Corporation, the Naval Post Graduate School and Wyle Labs supporting the National Reconnaissance Office.

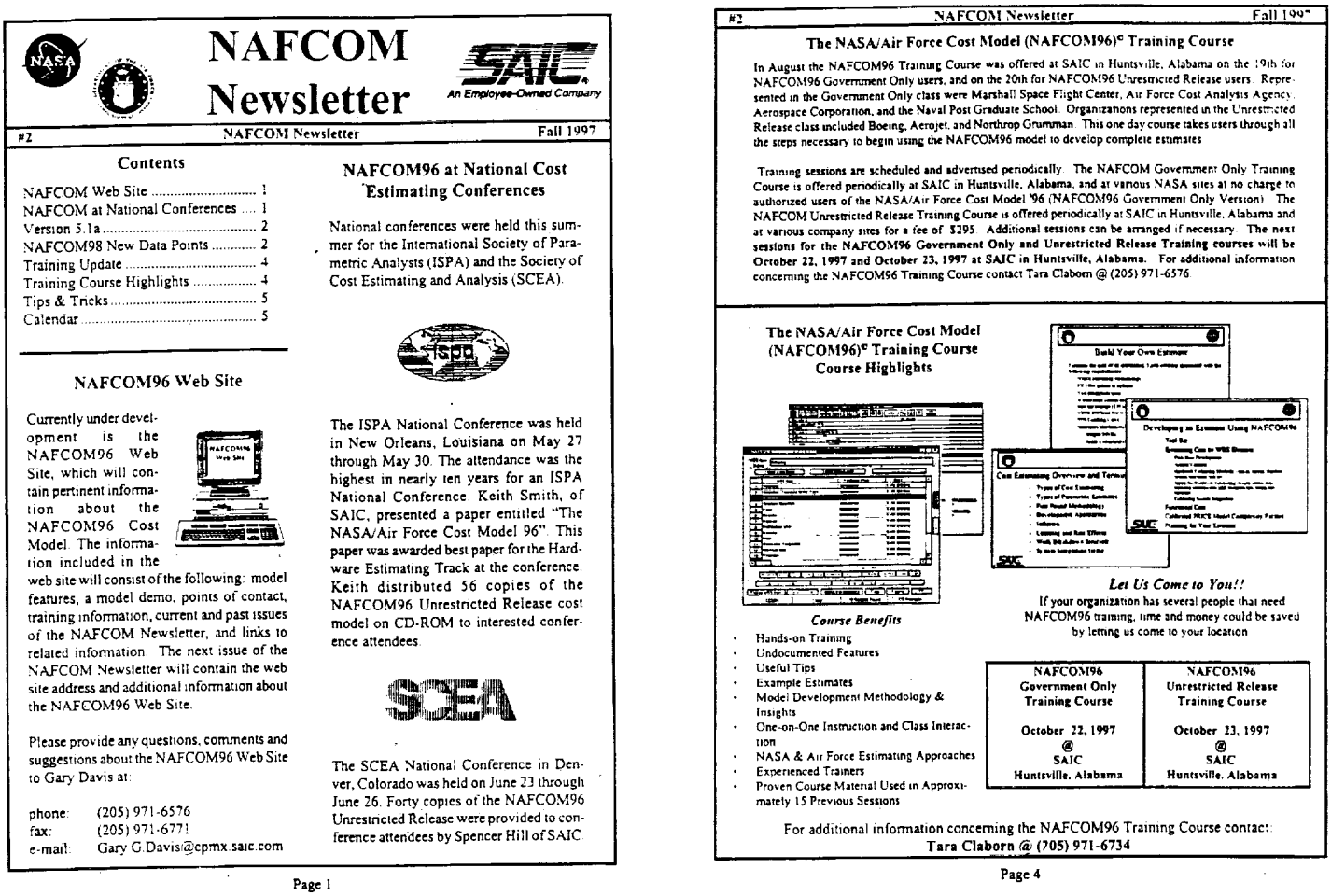
In addition to the government only courses, we conducted a course for the NAFCOM Unrestricted Release Version 5.1. Surprisingly only three people were able to attend the Unrestricted Release course. Attendees represented Boeing, Aerojet and Northrop Grumman. Hughes, Lockheed, and Pace & Wade have expressed interest in sending representatives to the class, but have had schedule conflicts.

II. 3.E NAFCOM Newsletter & Web Site

In an effort to improve communication to the cost estimating community about the features and uses of the NAFCOM cost model, we developed a NAFCOM Newsletter and a NAFCOM WWW homepage.

We published and distributed two issues of the NAFCOM Newsletter which provides information about both the Government Only and the Unrestricted Release versions of NAFCOM. The Newsletter is published quarterly and sent to all registered NAFCOM users, both Government and Unrestricted version users. We distributed over 500 newsletters this year. Two sample pages from one of our newsletters is shown in Figure 6.

This year we have also initiated development of the NAFCOM web site. The NAFCOM web site offers information concerning training, model features, current and previous newsletters, and contacts, and offers an on-line model demo. With the on-line model demo prospective users can get a feel for how NAFCOM works and the amount of data available within the model. Figure 7. shows the opening screen for the NAFCOM homepage.



NAFCOM Newsletter

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NAFCOM96 Web Site

Currently under development is the NAFCOM96 Web Site, which will contain pertinent information about the NAFCOM96 Cost Model. The information included in the web site will consist of the following: model features, a model demo, points of contact, training information, current and past issues of the NAFCOM Newsletter, and links to related information. The next issue of the NAFCOM Newsletter will contain the web site address and additional information about the NAFCOM96 Web Site.

Please provide any questions, comments and suggestions about the NAFCOM96 Web Site to Gary Davis at:

phone: (205) 971-6576
fax: (205) 971-6771
e-mail: Gary.G.Davis@cpmx.saic.com

NAFCOM96 at National Cost Estimating Conferences

National conferences were held this summer for the International Society of Parametric Analysts (ISPA) and the Society of Cost Estimating and Analysis (SCEA).

The ISPA National Conference was held in New Orleans, Louisiana on May 27 through May 30. The attendance was the highest in nearly ten years for an ISPA National Conference. Keith Smith, of SAIC, presented a paper entitled "The NASA/Air Force Cost Model 96". This paper was awarded best paper for the Hardware Estimating Track at the conference. Keith distributed 56 copies of the NAFCOM96 Unrestricted Release cost model on CD-ROM to interested conference attendees.

The SCEA National Conference in Denver, Colorado was held on June 23 through June 26. Forty copies of the NAFCOM96 Unrestricted Release were provided to conference attendees by Spencer Hill of SAIC.

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The NASA/Air Force Cost Model (NAFCOM96)© Training Course

In August the NAFCOM96 Training Course was offered at SAIC in Huntsville, Alabama on the 19th for NAFCOM96 Government Only users, and on the 20th for NAFCOM96 Unrestricted Release users. Represented in the Government Only class were Marshall Space Flight Center, Air Force Cost Analysis Agency, Aerospace Corporation, and the Naval Post Graduate School. Organizations represented in the Unrestricted Release class included Boeing, Aerojet, and Northrop Grumman. This one day course takes users through all the steps necessary to begin using the NAFCOM96 model to develop complete estimates.

Training sessions are scheduled and advertised periodically. The NAFCOM Government Only Training Course is offered periodically at SAIC in Huntsville, Alabama, and at various NASA sites at no charge to authorized users of the NASA/Air Force Cost Model '96 (NAFCOM96 Government Only Version). The NAFCOM Unrestricted Release Training Course is offered periodically at SAIC in Huntsville, Alabama and at various company sites for a fee of $295. Additional sessions can be arranged if necessary. **The next sessions for the NAFCOM96 Government Only and Unrestricted Release Training courses will be October 22, 1997 and October 23, 1997 at SAIC in Huntsville, Alabama.** For additional information concerning the NAFCOM96 Training Course contact Tara Claborn @ (205) 971-6576.

The NASA/Air Force Cost Model (NAFCOM96)© Training Course Course Highlights

Course Benefits

- Hands-on Training
- Undocumented Features
- Useful Tips
- Example Estimates
- Model Development Methodology & Insights
- One-on-One Instruction and Class Interaction
- NASA & Air Force Estimating Approaches
- Experienced Trainers
- Proven Course Material Used in Approximately 15 Previous Sessions

Let Us Come to You!!

If your organization has several people that need NAFCOM96 training, time and money could be saved by letting us come to your location.

NAFCOM96 Government Only Training Course	NAFCOM96 Unrestricted Release Training Course
October 22, 1997 @ SAIC Huntsville, Alabama	October 23, 1997 @ SAIC Huntsville, Alabama

For additional information concerning the NAFCOM96 Training Course contact:
Tara Claborn @ (705) 971-6734

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Figure 6. NAFCOM Newsletter

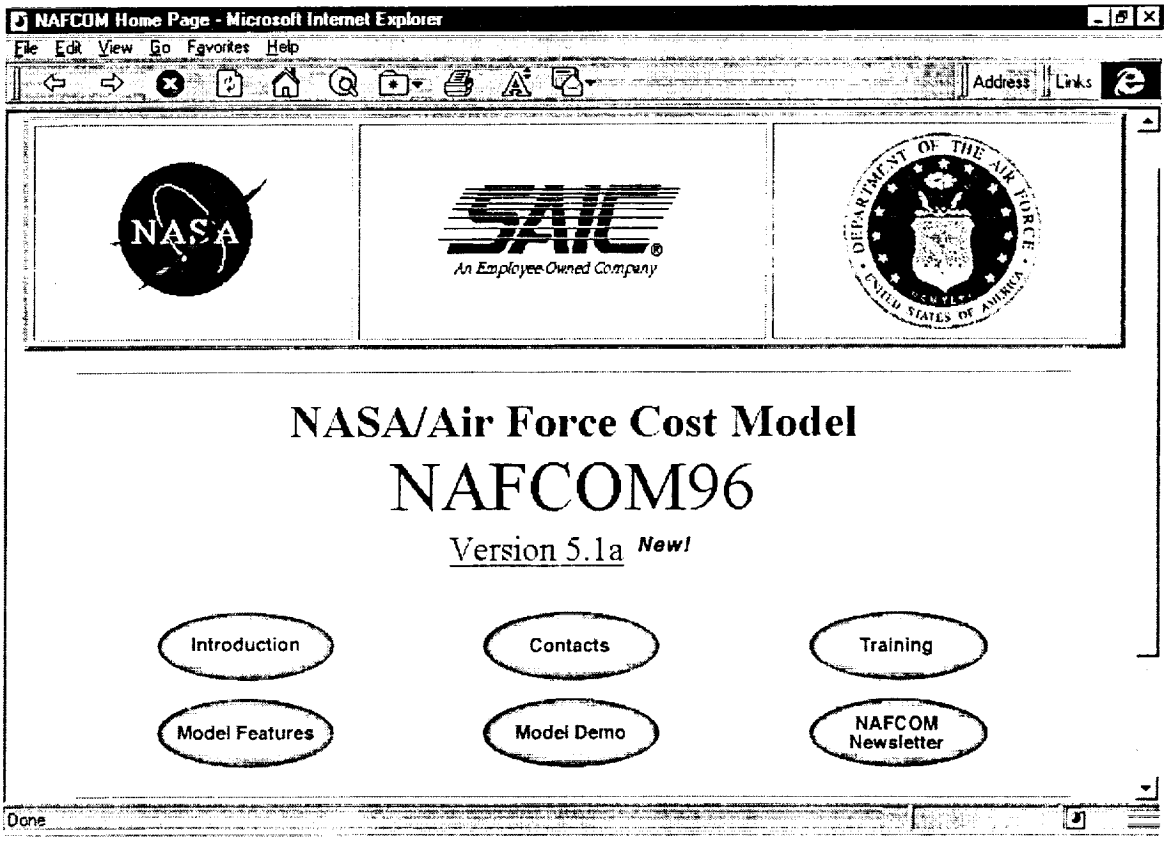

Figure 7. NAFCOM Cost Model Homepage

II.4 Schedule Development and Analysis

The establishment of a NAFCOM process based schedule module concept was initiated in this contract year. This began with a series of meetings at MSFC on how to direct the research effort on this task. Throughout the year this has been an ongoing commitment to establish a framework in which a process based schedule development tool can be implemented into the larger NAFCOM once the Version 5.0 and Unrestricted Release version were totally operational.

Subsystem schedules in REDSTAR were reviewed to identify processes that occur in various phases of subsystem design and development. Various papers, handbooks, and other publications were also reviewed to assure consistency with established standards and accepted practice. Preliminary schedules for generic avionics, structure, and propulsion subsystems have been developed. Critiques from subsystem design engineers are being sought to refine the preliminary schedules. Interviews have been initiated and will continue into the next contract year. A preliminary structures development schedule including the significant processes is shown in Figure 8. Similar schedules for the other subsystems are in various stages of development.

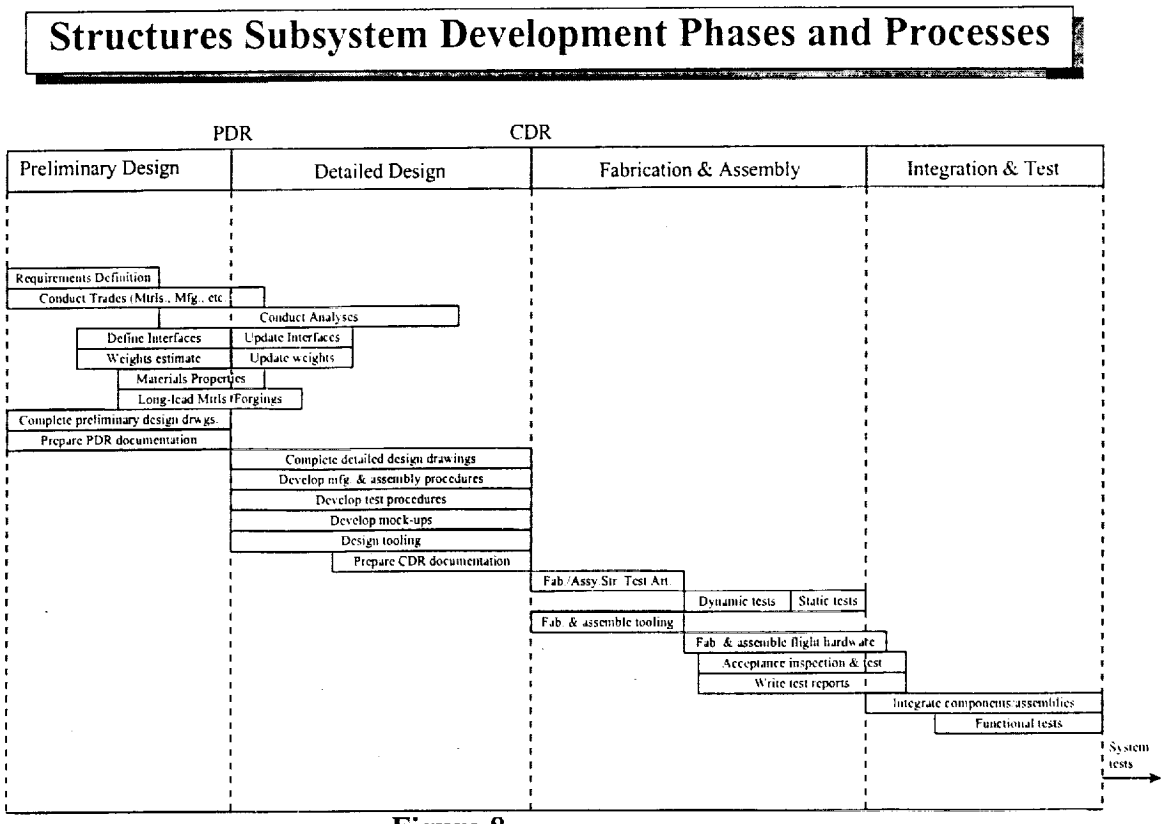

Figure 8.

In May SAIC compiled and delivered a complete copy of the Schedules Notebooks to PP02. There are 4 volumes of notebooks that contain hundres of schedules on historical, current, and study missions. These notebooks represent a significant acquisition of schedule data collected from MSFC personnel, other centers, contractors, and our own databases. This has enabled PP02 to have a ready reference of raw schedule data at their convenience. A duplicate copy of these notebooks is in the REDSTAR.

SAIC worked with PP02 personnel on making some minor adjustments to the calculations in the Schedule and Cost Optimization Model (SACOM). This was in response to a user's request.

In addition, several ad hoc requests for schedules and schedule related data were completed this past year. These requests were related to the following programs:

External Tank
SRB
SSME
Inertial Upper Stages

III. ADDITIONAL TASKING

In addition to the basic tasks accomplished for the Program Development directorate of MSFC, several in-scope tasks were performed under the contract for other NASA elements. Those tasks that were funded by the NASA Headquarters Comptroller Office were (1) the continuing effort to develop a comprehensive NASA Space Operations Cost Model., (2) the transfer of additional hardcopy REDSTAR Data Base documentation to CD-ROM format and distribution to NASA centers, (3) the development of a CD-ROM containing cost models called an Estimated Toolkit, and (4) the calibration of the PRICE Systems Cost Model for NASA users.

A task to provide cost estimating and modeling capability at the Ames Research Center, funded jointly by the center and the NASA Comptroller, was continued this contract year. A task to assess and validate the cost estimating capabilities of a MSFC-S&E model called COMPRE' was performed during the contract year. A MSFC funded task provided cost modeling enhancement for the MSFC Microgravity Project Office. Two tasks funded by the MSFC Space Transportation Office were undertaken during part of the year. These were the development of schedules for a number of hardware projects within the office, and the development of an approach to assess NASA launch vehicle technology efforts and develop a methodology to assure that the most cost effective technologies are approved and funded. Finally, two tasks, funded by the Air Force Cost Analysis Agency, were performed. One was to add Air Force unique requirements, to NAFCOM and underwrite part of the Complexity Generator development. The second task was to perform an assessment of the Cost Analysis Requirements Document for the Global Broadcast System.

In this area of additional taskings, there are again a large number of products developed and provided to the government. Some examples are a prototype version of the Space Operations Cost Model, CD-ROMs containing 2,500 documents from the REDSTAR library, Version 5.0 of the Microgravity Experiment Cost Model a new section in the PRICE Calibration Handbook, an approach for the development of a space transportation technology assessment tool, a comprehensive assessment of a Air Force Cost Analysis Requirement Document, development schedules for new space transportation elements, and an evaluation of the costing capabilities of a MSFC-S&E assessment model.

The additional tasks provide synergistic elements to each other as well as to the basic MSFC effort. Additionally, they often draw upon the data contained in the REDSTAR and NAFCOM data bases, utilize the NAFCOM Cost Model, and tailor the methodologies developed under the basis contract to their needs so that uniform, compatible, and cost effective products are obtained by all NASA and Air Force customers. The specific work performed in each of these tasks during this contract year is described in the following paragraphs.

III.1 Ames Research Center Cost Analysis

SAIC has one full-time cost analyst working at the NASA Ames Research Center (ARC) to perform cost estimates, develop models, and keep ARC informed on the latest developments in NASA cost estimating.

One of the tasks we worked on this year was to develop a process-based estimating tool for wind tunnels. We developed a preliminary tool based on very good high-level data that provided probabilistic cost and manpower estimates related to wind tunnel processes. The plan was to evolve this tool to a lower level. The wind tunnel personnel could not provide the test data and cost data at a low enough level to advance the process-based tool. Because of the lack of data ARC decided to explore other areas for the development of a process-based cost estimating tool. It was decided that we would use Explorer class missions as the basis of the process-based tool. Specifically we are currently using Lunar Prospector as a basis for the model and have begun breaking it down into specific activities and flow charts.

The ARC person has also done a significant amount of development on the Ames WWW Homepage related to the cost estimating capability at ARC and also on the development of the NAFCOM Homepage. This information will be linked to both ARC and MSFC web pages.

This year we also began developing an independent cost estimate for the Kepler mission. NASA will be competing on an Announcement Opportunity (AO) in the near future and we are performing an independent estimate and an analysis of the project estimate for the cost of this mission.

As part of our responsibility to keep ARC informed on recent cost estimating developments, we conducted a NAFCOM 96 training class at ARC. Eight ARC employees attended this training.

III.2 REDSTAR Library Scanning Effort

This year we continued the scanning effort for the REDSTAR Library by completing the scanning of the second 2,500 documents and beginning the scanning of the next 2,500 documents. Ten sets of CD-ROMs are currently being distributed to NASA Centers with an additional 15 CD in each. This puts the REDSTAR CD-ROM set at 30 CDs per set, 5,000 documents, over 350,000 pages of information, and 19,500 megabytes of data. We have scanned approximately 2000 of the documents for the last set of 2,500 documents from REDSTAR. This set should be delivered in February 1998.

III.3 Estimator's Toolkit

In this contract year, we developed a collection of cost models and an interface from which to access these models, which is called the "Estimator's Toolkit". Automated models can actually be used from the CD or can be installed onto a computer's hard drive. Models that are in hard copy format only were scanned and can be viewed from the interface. Users are provided with evaluations of each model which give features, histories, advantages/disadvantages, ground rules, etc. Currently, 15 models are included on the CD. This model has been completed and is currently being duplicated for distribution. A sample screen from the Estimator's Toolkit is shown in Figure 9.

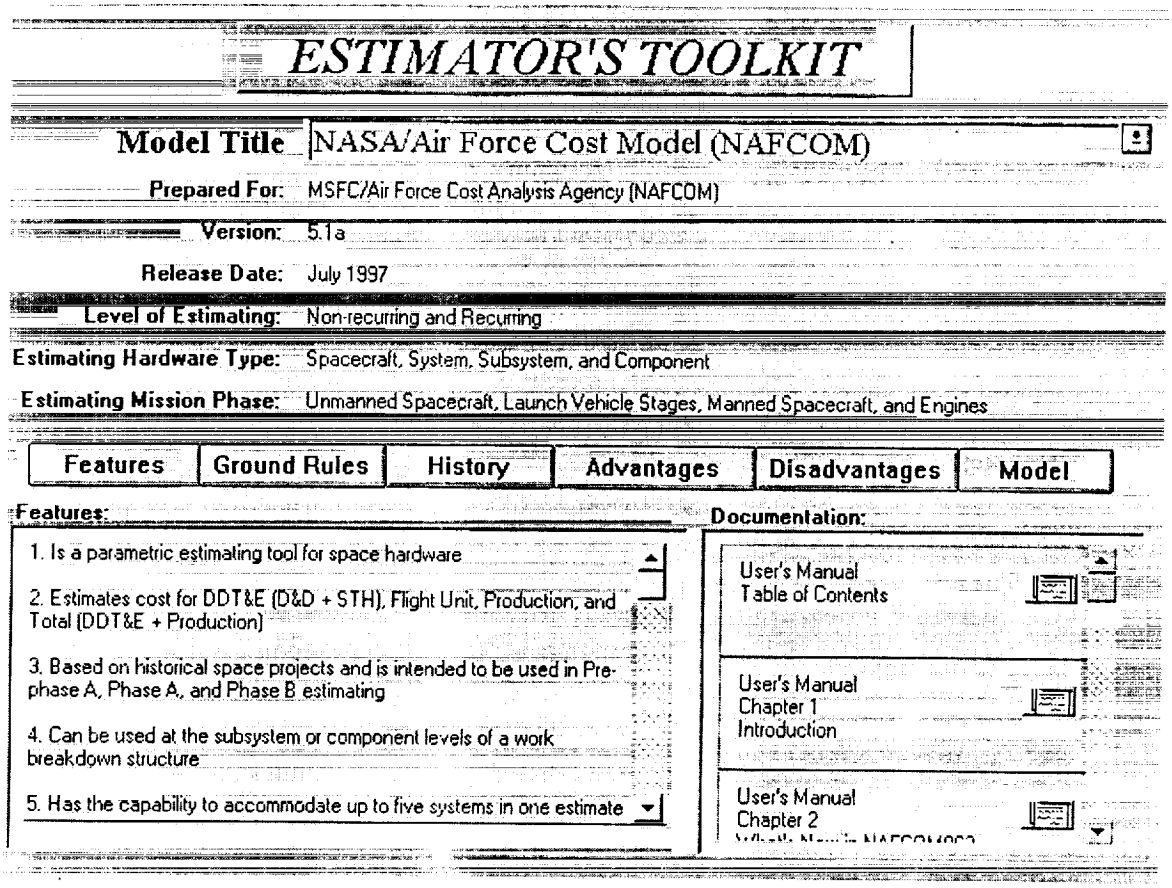

Figure 9. Estimator's Toolkit Model Screen

III.4 PRICE System Calibration

In this contract year, SAIC improved the PRICE Calibration Handbook, furthered the PRICE Calibration Exercise, and assisted NASA PRICE Systems users at MSFC with a variety of exercises involving the PRICE Model.

An entirely new chapter was added to the PRICE Calibration Handbook. This chapter, entitled "Applying the Results", assists users in generating new estimates using

the calibrated data supplied in the Handbook. The new section informs users of specifically where and how to find analogous data points and calibrated MCPLXS values in the Handbook and in the NASA/Air Force Cost Model (NAFCOM). A quick reference table was included that summarizes the calibrated complexities which would be utilized in a new estimate. After approval by Del Wilson at NASA Headquarters, the additional chapter was distributed to PRICE users NASA-wide who currently holds a copy of the handbook.

There has been expressed interest from the NASA community in additional calibration of the model, such as calibrating development schedules and integration and test costs. Early in the year we began researching and documenting an approach to calibrate NASA schedules to the PRICE Model. Very few schedules exist at the subsystem level, but there seems to be enough data to calibrate PRICE's schedule variables. We plan to begin this calibration process in the next contract option year.

Based on response from the NASA community, it was decided that the next step should be to calibrate the costs associated with integrating the subsystems into a system, called in PRICE the Integration and Test (I&T) costs. This calibration is needed for an estimator to generate an estimate based totally on calibrated data. Since the PRICE calibrated data has been incorporated into NAFCOM at the subsystem level, it would be beneficial to have the calibrated integration and test values to include as well. Thus far the NAFCOM system level wrap cost have been collected and reviewed. These are the cost to which the PRICE Model's Integration and Test will be calibrated. To aid in developing a calibration methodology, a mission data file (Orbiter) is being utilized as a test case. Once the best methodology is developed, calibration of other missions will begin.

The PRICE Calibration Handbook will be updated with the Integration and Test results and redistributed when the calibration is completed. The Handbook's distribution list has been updated. PRICE Systems has provided SAIC with a new list of registered PRICE users at NASA centers. By incorporating this list, the disbribution list has increased to 81 users.

In addition to the calibration efforts, SAIC has assisted NASA PRICE users with estimates, which in most instances utilized results from the calibration effort. SAIC assisted MSFC in determining an appropriate breakout for development and flight hardware for an estimate, based on historical PRICE estimates and sample runs. Also an estimate previously performed using PRICE was recreated and observed the change in costs when the weights were changed. In addition, "business as usual" and "new ways of doing business" estimates of the latest configuration of the X-33 vehicle using the PRICE model were supported.

III.5 Space Operations Cost Model

The NASA Space Operations Cost Model (SOCM) development study is an ambitious task to develop a NASA agency-wide operations cost model. Operations types include robotic planetary and Earth orbiting science missions, as well as transportation systems, space facility, and ground facility operations support for robotic and/or human spaceflight missions.

The SOCM study team is lead by an inter-center Steering Committee. SAIC is currently leading efforts to construct the rapid prototype model (RPM) versions, collect and integrate Steering Committee and user community feedback, and to test the RPM versions against a range of mission types and data sets.

SOCM is a tool to estimate the operations costs associated with a NASA spaceflight mission. For robotic science missions, this includes all of Phase E, with the exception of post-launch development and post-flight activities (as shown in Figure 10. below). Several SOCM RPM versions have been completed and tested for these mission types.

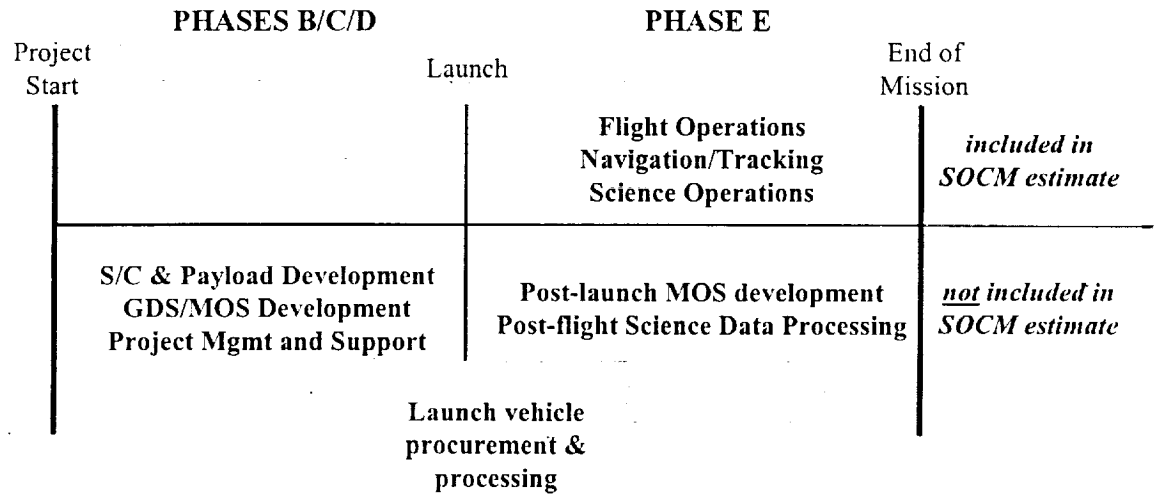

Figure 10. SOCM Estimate Scope for Planetary and Earth Orbiting Modules

SOCM will also estimate operations costs associated with other mission types including: Transportation Systems, Space Facilities, and Ground Facilities. These mission types can support robotic and/or human spaceflight projects. The SOCM estimating methodology for these is currently being developed from data collected from the Space Station and Space Shuttle projects and from results/findings of past operations modeling investigations. A preliminary high-level operations cost estimate breakdown structure currently being investigated in a SOCM RPM for these mission types is shown in Figure 11. It includes costs for five operations support elements (Flight Ops/Ground

Ops/Application Ops/Navigation Ops/Operations Services) distributed across four operations phases (Pre-Launch/Launch/Flight/Post-Flight).

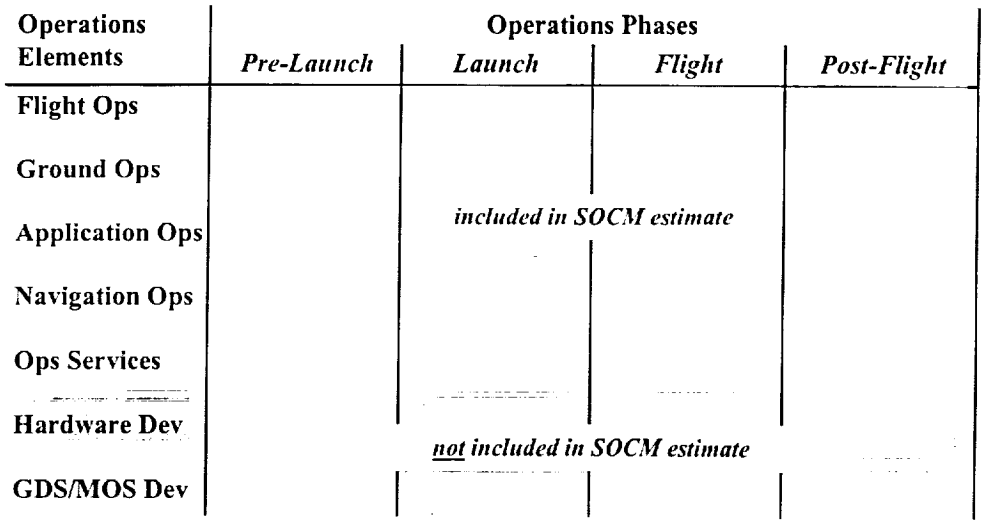

Figure 11. SOCM Estimate Scope for Modules to Support Robotic and/or Human Spaceflight Missions

An innovative model development approach has enabled construction of continually-improving SOCM RPM versions. One of the key features of SOCM is that it is a constructive model that captures the relative impacts of operations cost drivers on specific mission types and operations support elements and activities. The model is tuned to cost, performance, and programmatic data collected at various levels of detail and cost driver values are defined in terms of current state-of-the-practice technology levels. SOCM RPM versions are tested and reviewed by the Steering Committee and user community to identify areas for improvement and direct future data collection efforts. SOCM's estimating methodology is extremely flexible, facilitating rapid incorporation of comments and recommendations for improvements from a broad user community. SAIC provides a point-of-contact for collecting user feedback and integrates comments received into RPM versions.

III.5.A User Community Involvement

The SOCM user community has grown significantly over the past year. The planetary module was recently used to support the Discovery Program AO Proposal Evaluation at NASA LaRC. Feedback obtained from the Discovery Program Office was very positive, and the results were used to evaluate operations support strategies for the Discovery mission candidates.

A RPM version of the Earth orbiting module was prepared and presented to NASA GSFC RAO and Code 500 staff. A group of Code 500 operations specialists have been working with SAIC to identify changes/enhancements needed to complete this module. GSFC Code 500 has provided SAIC high-level data on several advanced Earth

orbiting mission concepts to use for testing and tuning the performance of the Earth orbiting module. The methodology used for Earth orbiting missions has been revised to incorporate findings from these efforts and additional feedback is still being collected.

In an effort to help users better understand the SOCM estimating approach, a set of four sample mission concepts was developed by SAIC and distributed to the Steering Committee. Preparations are underway to conduct a SOCM tutorial/demonstration at the first Steering Committee Quarterly Meeting of 1998 (at JSC in January) using these sample mission concepts. SAIC is completing many model improvements to support this meeting including a refined estimating methodology, incorporation of operations support service cost impacts, and an improved user interface. These refinements address most of the suggestions and recommendations collected from the Steering Committee and other SOCM users.

The Steering Committee is currently identifying potential users from the transportation systems, space facility, and ground facility communities. Space Station operations experts at JPL and JSC and transportation system experts at MSFC have been identified and are currently working with the SOCM team to develop methodologies for the remaining modules.

III5.B SOCM Study Products

A variety of study products have been generated and are described in the following table. Copies of any of the SOCM products listed can be made available upon request.

SOCM Study Products

Item	Description
SOCM Rapid Prototype Models (1a, 1b, 2a, 2b, 2c, 2d)	Rapid prototypes developed to incorporate user feedback, test estimation methodology options on various data sets, and as a communication aide between SOCM modeling teams, data collection teams, and the user community; SAIC is leading the development of these rapid prototypes and serving as a point-of-contact to collect and integrate information/data/findings.
SOCM User Manual and Guide	Manual for operating the SOCM software and an overall description of the model; The manual is being written by SAIC and the description/guide is being written by GSFC and SAIC.
ISPA Conference Paper (May)	A general description of the overall SOCM study effort was prepared by SAIC and NASA HQ and presented at the ISPA conference.
Quarterly Steering Committee Reports (Jan/Apr/Aug/Oct)	SAIC status updates for specific SOCM modules and presentation of advanced concepts; Includes a performance assessment and testing results for latest rapid prototype version.
Data Collection Report (Aug)	Summary of SAIC data collection efforts for Space Shuttle and Space Station.
Earth Orbiting Module Rev w/ GSFC RAO&Code500 (Sep)	SAIC presentation of a preliminary Earth Orbiting module prototype to obtain feedback and guidance for future efforts from operations cost and technical experts.

III5.C Current Status of Specific SOCM Modules

SOCM currently includes five modules that share a similar estimating methodology, but each with a unique set of cost drivers and estimating categories. Two modules, planetary and Earth orbiting, are functional. Methodologies for the remaining modules are currently being defined/developed. The status for each SOCM module is summarized in the table below.

Status of Specific SOCM Modules - December 1997

SOCM Module	Status
Planetary Space Science Missions	Several prototype versions completed and successfully tested; User feedback is still being collected and rapidly integrated into the model; This module is fully functional and future changes are mainly enhancements.
Earth Orbiting Science Missions	Several prototype versions have been completed, tested, and presented to potential users; Some issues regarding significant differences between Planetary and Earth Orbiting missions have required changes to the SOCM estimating methodology; These changes have been made and this updated module is currently being retested and redistributed to the user community.
Transportation System Operations *Earth Launch Vehicles* *In-Space Transport.* *Surface Exc. Vehicles*	A general approach has been developed and results from past modeling efforts have been collected for review; A user community for this module has been identified and plans are currently being made to meet and discuss ways to integrate their relevant past findings.
Space Facility Operations *Orbital Facilities* *Planetary Surface*	A general approach has been developed and results from past modeling efforts have been collected for review; Developers of a detailed Space Station operations model (1991 JPL/JSC MESSOC) have provided their model and background reports/data to our team to help identify cost drivers for space facilities; Key members of the JPL/JSC MESSOC model development are currently participating with the study to facilitate incorporation of relevant findings from their efforts into SOCM.
Ground Facility Operations *GDS/MOS* *Flight Sys Processing* *Application/Sci Ops*	A general approach has been developed, but needs some refining; The SAIC GOCM model developed for KSC will be used to identify relevant cost drivers; Representatives from KSC are currently being identified to provide guidance for this module.

III.6 Air Force Cost Analysis Agency (AFCAA) Task

The Complexity Generator research continues to date. Once containing many cost drivers, both technical and programmatic per subsystem, the Complexity Generator has now been somewhat simplified. We are using TRLs (Technology Readyness Levels) as a major driver. With TRLs receiving the major cost benefit, the Complexity Generator can now focus less on insignificant drivers and more on the actual mission cost and relative technology. (An example of this methodology can be seen in Figure 12). The variance seen in the TRL of missions from the past five years and missions from earlier time periods are enough to explain much of the here-to-fore inexplicable cost. With more TRL

research, the Complexity Generator problem is certainly a solvable problem. The Complexity Generator represents a methodology whereby hardware performance, program nuances, design maturity levels, and management efficiencies/inefficiencies are identified, documented, and understood for all NAFCOM data. The completion of the Complexity Generator analysis will be some time in the early spring of 1998. The final effort in the coming contract performance period will entail the statistical derivation of equations and verification of their application as a viable estimating tool.

In addition, this year the Air Force launch vehicles from the LVCM cost model have been added to the NAFCOM data base. These data have been analyzed and appropriately modeled to reflect the Air Force approach to their development. Included are: Pegasus XL, Atlas II, Titan IV and Delta (recurring cost only), Minuteman, and Peacekeeper.

MISSION	TRL	DDT&E/ PREDICTED	DDT&E	PREDICTED DDT&E	WEIGHT	SC_CLASS	LAUNCH YR
HEAO-3	9.00	0.092	0.758	8.201	148	Observatory	1979
LANDSAT-4	9.00	0.096	1.562	16.275	299	Mapping/Meteorological	1982
RADCAL	9.00	0.098	0.369	3.749	66	Positioning	1993
REX	8.80	0.179	0.215	1.200	21	Communication	1991
STEP2	8.77	0.204	0.639	3.125	55	Communication	1994
P78	8.70	0.273	2.604	9.538	173	Scientific	1979
STEP3	8.67	0.282	1.100	3.898	69	Scientific	1995
ERBS	8.63	0.285	4.954	17.389	320	Scientific	1984
SME	8.62	0.288	0.883	3.064	54	Scientific	1981
UARS	8.50	0.360	9.146	25.397	472	Scientific	1991
UFO	8.30	0.408	25.622	62.803	1195	Communication	1993
FREJA	8.20	0.427	1.003	2.347	41	Scientific	1992
HETE	8.20	0.434	0.752	1.731	30	Scientific	1995
DSCS-IIIB	8.20	0.435	16.312	37.467	703	Communication	1984
DE-1	8.20	0.438	2.332	5.324	95	Scientific	1981
STEP1	8.15	0.444	1.607	3.622	64	Scientific	1995
ALEXIS	8.15	0.445	0.519	1.166	20	Scientific	1997
MACSAT	8.15	0.447	1.055	2.358	41	Communication	1990
GRO	8.12	0.450	10.129	22.492	417	Observatory	1991
DE-2	8.10	0.481	2.456	5.105	91	Scientific	1981
AEM-HCMM	8.00	0.520	0.753	1.449	25	Scientific	1978
STEP0	7.95	0.539	1.982	3.678	65	Scientific	1994
ORSTED	7.90	0.574	0.734	1.279	22	Scientific	1994
TOPEX	7.88	0.589	12.371	21.018	389	Mapping/Meteorological	1992
CRRES	7.70	0.643	4.800	7.460	134	Scientific	1990
COBE	6.50	0.904	10.193	11.277	205	Scientific	1989
DARPASAT	6.20	0.936	2.196	2.348	41	Reconnaissance	1994
INTELSAT-III	5.95	1.090	11.228	10.301	187	Communication	1969
SWAS	5.90	1.138	3.196	2.809	49	Communication	1993
AMPTE-CCE	5.65	1.300	2.768	2.129	37	Scientific	1984
TOMSEP	5.65	1.300	3.124	2.403	42	Mapping/Meteorological	1996
S3	5.35	1.518	3.003	1.978	34	Scientific	1974
TACSAT	5.30	1.570	24.990	15.920	292	Communication	1969
MICROSAT	5.30	1.574	1.197	0.760	13	Communication	1991

An R-value of 0.823 is obtained when the NAFCOM Unmanned Spacecraft data base for CC&DH is regressed against weight and TRL (Technology Readiness Level).

Figure 12. Methodology Example

III.7 Air Force Cost Analysis Agency GBS CARD Review

In the April, May, June time frame, SAIC provided independent and cost analysis to the AFCAA in the assessment of the Cost Analysis Requirements Description (CARD) for the Global Broadcast System (GBS). SAIC performed a comprehensive review of the CARD noting deficiencies, omissions, areas of potential misunderstandings, and errors. We further provided technical support to Air Force reviews and reconciliation meetings in Washington. SAIC further identified the high risk/high cost areas independently of the Program Office Estimate (POE) and analyzed sufficiency review areas that were not covered by the high risk/high cost areas. Comprehensive review comments were delivered to the AFCAA on April 18 and additional comments again on June 19. Included were a paper trail of reconciliation of deficiency corrections and critical review of CARD sections that were added after the initial review. The SAIC review concluded that the identified concerns were addressed and that recommendation for correction were incorporated into the revised card. This short-term task effort concluded at the end of June.

III.8 Microgravity Research Program Office Cost Analysis

SAIC has performed a maintenance level of effort on the Microgravity Experiments Cost Model (MECM) this year. Our primary task has been updating the data base and CERs within the model to account for more low cost spacecraft data. We were able to use data that was collected as part of our NAFCOM Cost Model data collection efforts for MECM. The new data was normalized into the MECM ground rules, the CERs were regressed and analyzed, and new CERs were incorporated into the model. We were also required to update the programming of the model to accommodate changes in Excel in Microsoft Office 97.

An updated version of the model, MECM 5.0, was completed and delivered in this contract year including updated software and a new User's Manual.

III.9 COMPRE' Cost Model

The object of this study was to exercise the Complex Organizational Metric for Programmatic Risk Environments (COMPRE') model using compiled historical project data to assess the model's predictive capabilities and identification of any necessary modifications and calibrations. The study considered numerous past National Aeronautical Space Administration (NASA) programs in an attempt to have the model predict or estimate the technical, cost and schedule risk associated with their respective architecture, technology readiness, and organizational hierarchy. These programs were selected to represent a variety of factors, such as mission objective, organization involvement and anomalies in schedule and cost.

The validation and verification efforts on COMPRE' were completed as planned. There was several additional programs run through the model to provide a wider spectrum of program data points. Several of the new programs were low-cost and one was a mid-level program that was within budget and schedule. The model provided results that appear to appropriately represent the relative Expected Program Risk and the relative Expected Technology Payoff of the completed programs. Our findings indicated that the COMPRE' Model has the potential to be a useful program manager's programmatic risk management tool.

Having completed all work associated with this project, the Final Peer Review was held and the Final Report delivered September 12, 1997.

III.10 Space Transportation Office Technology Assessment

The central objective of this task has been to design and develop an integrated agency-wide process for annually prioritizing candidate space transportation technology investment opportunities (TIOs) to maximize the return on the investments to NASA. Because of the complexity of the problem, SAIC created and recommended a sequential, multilevel process approach to NASA which begins with any set of potential TIOs and produces a recommended portfolio of technology investments for validation and approval by NASA as an input into the annual budget development process.

SAIC has facilitated the work of the interCenter Systems Working Group (SWG) in developing and reviewing the resulting four-level Technology Investment Prioritization Process and associated Technology Investment Prioritization System (TIPS) facilitation software. The overall process has been designed, reviewed and briefed to NASA management and industry. It has been received with enthusiasm. The TIPS prototype software has been demonstrated to the SWG and to the U. S. Air Force. Level I of the process provides a qualification analysis to screen potential TIOs to identify those that are the most promising candidates based on a defined set of evaluation criteria. Level II of the process provides for integrated systems and economic analyses to determine the TIOs that are the most promising ones economically as investments. These are passed on to Level III in which the Analytic Hierarchy Process (AHP) is used to prioritize the TIOs against the economic and non-economic criteria considered important by NASA management in evaluating candidate technology investments. In Level IV, the prioritized TIOs by systems/projects are integrated into a recommended portfolio of investments based on overall prioritization against NASA strategic space transportation objectives. Automated documentation features are being developed in TIPS to provide a variety of reports on the prioritization process results. TIPS also provides a very flexible capability to respond to "what if" questions during the portfolio review and validation process by a national level space transportation technology council.

This effort is being transitioned to another MSFC-SAIC contract and will not be continued under this contract. A meeting of the SWG in December 1997 is planned to

review the technology investment opportunity database format, the Level I, II and III evaluation criteria, and the schedule for accomplishing the a technology investment prioritization process demo using the Single Stage to Orbit Reusable Launch Vehicle (SSTO/RLV) as the reference system for continuation. The demo experience and lessons learned will support the follow-on effort to prioritize TIOs for the systems involved in the FY 2000 budget development effort during 1998.

III.11 Space Transportation Office Schedule Development

During the period of December 1, 1996 until August 8, 1997 SAIC provided the expertise for schedule development to the Advanced Space Transportation Program (ASTP). This effort consisted of developing schedules for the Shooting Star Experiment (SSE), the Low Cost Boost Technologies (LCBT) Propulsion Test Article (PTA) 1, the NASA Research Announcement (NRA) 8-17, PTA2, and NRA 8-19. The schedules were developed, maintained, and statused on a daily basis. These schedules became a part of the ASTP summary level schedule book and given to the program manager at monthly intervals.

The SSE project schedule was developed from information gathered from project personnel. This information consisted of identifying the tasks to be accomplished, the amount of time necessary to complete the tasks, and the sequence in which these tasks were to be completed. Many one-on-one meetings were held to discuss the sequencing of tasks and the items identified as being on the critical path. After completion, the schedule was delivered to the project and is currently being maintained by government personnel.

The PTA1 schedule was expanded upon from a previous version received from the project manager. The schedule had been baselined the month prior to this period of performance. The project manager requested that the schedule be updated and maintained on a daily basis. The requirements for the project changed significantly during the period of performance and this required daily updates to the schedule. The critical path report of the schedule was produced and briefed to the MSFC Center Director weekly. After significant growth of the schedule, it was determined that a monthly status to the entire schedule was feasible. The critical path report was still generated on a weekly basis and the items that were determined to be project critical were updated weekly. An example of the schedule is shown in Figure 13.

The NRA 8-17, NRA 8-19, and PTA2 schedules were developed using information gathered from the project manager. The NRA 8-17 schedule was developed from several contractor schedules. The contractor inputs were received via electronic mail then merged together into one schedule. The contractor schedules were updated on a monthly basis. The NRA 8-19 effort was in its infancy and a summary level schedule of the activities was prepared. The PTA2 schedule was developed and maintained on a monthly basis.

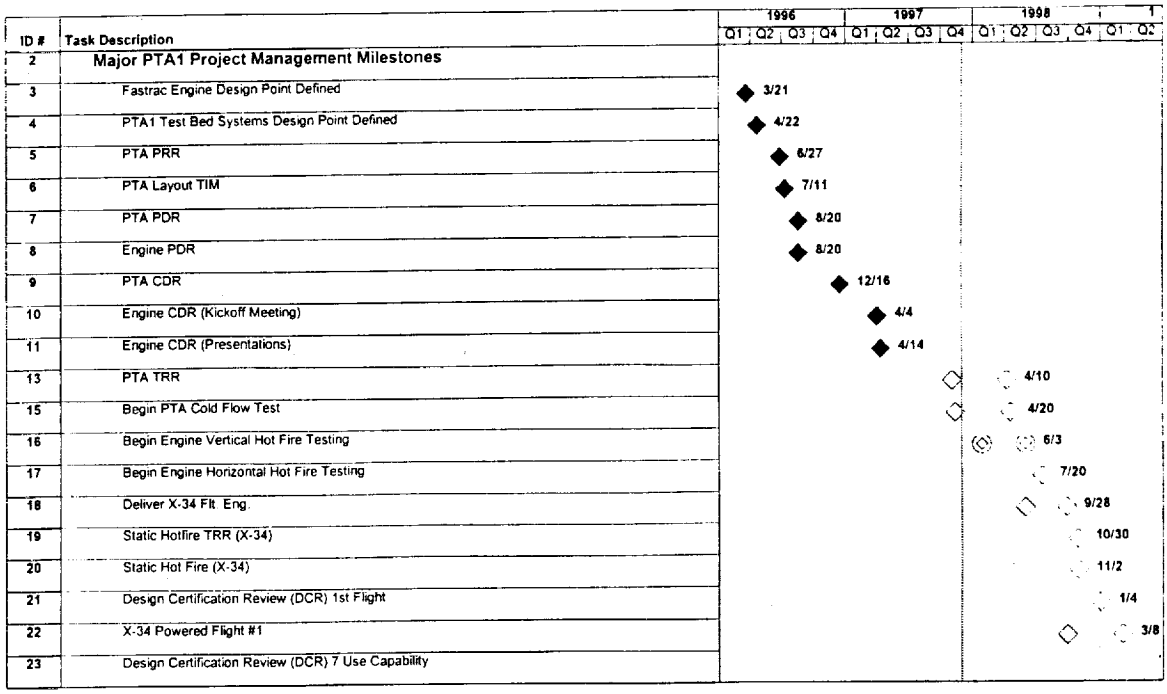

Figure 13. Propulsion Test Article (PTA) 1